Ocean-Related Senior Design Projects for Mechanical Engineers at UMass Dartmouth[1]

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Abstract

This paper discusses several ocean-related capstone design projects completed by mechanical engineering students at the University of Massachusetts Dartmouth. Some projects are detailed analytical projects that involved complex simulations, others are systems engineering projects that involved manufacturing and prototype testing. Different aspects of the design process are emphasized by the different styles of project, and all met with success. Several projects were performed in collaboration with other Departments at UMD or with local institutions that work in the oceanographic field. Neither students nor faculty advisors were assigned specific projects, yet nearly one third of the capstone design projects completed in the last three years have had an ocean or marine emphasis.

Introduction

Mechanical Engineering students at the University of Massachusetts Dartmouth (UMD) are required to take a capstone design course in their senior year. Until fall 2002, this 4-credit course was offered during the spring semester only. Beginning in the fall of 2002, the course was changed to a 2-semester sequence, offering 2 credits for each semester. In the fall semester, students are expected to form design teams, select a design project, secure a faculty advisor for that project, write a project proposal that includes both a schedule and a budget, and begin design work. Another major component of the fall course is practical engineering ethics. During the spring semester, the students are expected to complete their design projects, write a comprehensive final report, and publicly present their design projects before the faculty, a panel of judges from industry, and their fellow students. Students meet weekly with both their project advisor and the course facilitator, and write weekly memos updating their progress.

Although there is no formal program at UMD for ocean or marine-related engineering, several senior design projects of late have had a marine emphasis. On occasion, these projects have a connection with other departments or facilities of the University of Massachusetts or local research institutions. For example, one project was conducted through the Center for Marine Science and Technology (CMAST), a UMass-affiliated research laboratory that has recently started a Ph.D. program. One project was done in conjunction with the Woods Hole Oceanographic Institution, one of the US premier ocean research facilities; and another project was completed jointly with students

[1] The author was the course instructor for all projects presented in this paper; however, the author was not necessarily the project technical advisor. The information presented in this paper was obtained through meeting with the students and the project proposals and reports submitted by the students for the course.

in the senior design course from the UMD Electrical and Computer Engineering Department. This paper discusses several of the marine-related design projects that have recently been completed and the successes and failures of these undertakings. The projects are: 1) a large oceanographic tripod, 2) a remotely operated underwater vehicle, 3) an outboard motor mount for vertical and pitch control, 4) an acoustic toy for dolphins, and 5) a small expendable oceanographic profiler.

Oceanographic Tripod

In the spring of 2001, three students elected to design a large oceanographic tripod that would function as a stable platform for oceanographic and meteorological sensors [1]. This tripod would be deployed approximately 4 km off the coast of Martha's Vineyard, MA in approximately 19 m of water. Deployment time would be a minimum of 16 months, with the potential of extending beyond 2 years. The tripod, which would stand approximately 27 m tall, would support the coupled boundary layer air-sea interaction experiment in low-moderate winds (CBLAST-Low), in which the Woods Hole Oceanographic Institution was participating. The experiment was a large research program funded by the National Science Foundation to study air-sea interaction and many scientists from the oceanographic and meteorological community would be designing experiments and instruments that would be mounted on this platform. Some of the more difficult design requirements were that the structure had to not only survive the extreme currents and waves of New England storms, but also withstand a Class 3 hurricane. Further, as highly precise ocean current measuring devices were to be attached, the tripod had to interrupt the water flow as little as possible. Other criteria included the ability to support the weight of 3 persons during service visits and the ability to resist biofouling that would disable the sensors.

Figure 1 shows the tripod design. The lower platform, indicated by letter J, would stand just above sea level during calm seas. The tower, letters A, F, and D, would support wind monitoring, data transmission, and possibly video of the tripod itself. The leg design was the most creative and novel part of the project. As the flow measurement instrumentation would be located effectively in the middle of the tripod legs, the sensor being suspended from braces T, small thin legs with minimal impact on the local flow were desired. This effectively eliminated the cross-bracing techniques that are usually employed in oceanographic tripod design. The student-developed double-leg design minimized flow irregularities but still provided the strength needed to withstand the potential current and wave forces.

This project required the students to apply their fluids knowledge to calculate both wind and current forces on the tripod, but also required them to study wave forces, a topic not covered in any undergraduate or graduate courses at UMD. This they did with moderate success. The complexities of 3D dynamic forcing functions based on hypothetical wave spectra were difficult for the students and beyond their experience. Regardless, the project included stress analysis using the IDEAS finite element software on the legs and feet of the tripod. The iterative design process was well-served, as the results of the analysis aided design improvements. Manufacturing issues that were influenced by the sheer size of the tripod were further complicated by potential deployment methods and associated costs.

The final product for this design team was a preliminary design that in general met all of the design requirements. The students learned the design process and gained an appreciation for the wide variety of issues that must be addressed in design, and the students gained confidence in their ability to contribute to real-world engineering problems. In this sense, the project was a tremendous success; however, because the background learning curve was long and steep, the final product did not appear to be as advanced as other projects. Subsequent to the students completing the project, the Woods Hole Oceanographic Institution began to adapt their design to specific sensor constraints, but unfortunately, shortly thereafter, the overall design requirements changed enough that the design the students had developed was no longer suitable.

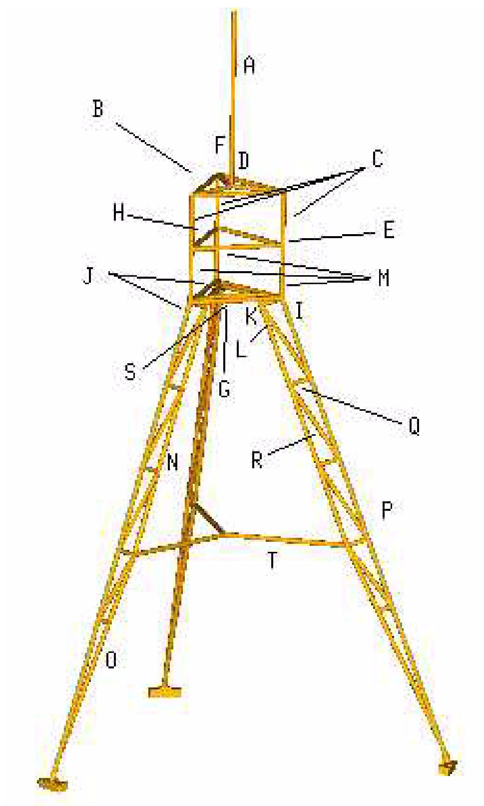

Figure 1. Oceanographic tripod.

Remotely Operated Vehicle (ROV)

Three students in the spring of 2002 elected to design and build their own remotely operated underwater vehicle [2]. With the financial backing of one student's parents, they designed a radio-controlled semi-tethered ROV for shallow water operations such as hull inspection and marine life viewing. The 36 lbf ROV, shown in Figure 2 was approximately 3 ft long with a hull diameter of 6 inches. Two PVC battery tubes were mounted on the sides, and the 12 volts supplied by six 2-volt rechargeable batteries connected in series was enough power to operate the vehicle for almost 45 minutes. A ¼ hp motor power gave the ROV forward and reverse maneuverability, and a water thrust system in the front half of the vehicle controlled pitch and yaw. An air-bladder ballast system enabled the vehicle to be neutrally buoyant to depths up to 30 feet, but a tether to a surface buoy prohibited maneuverability below 12 feet. Figure 3 shows a schematic of the ROV system, including the tether, the surface buoy, and the radio control. The surface buoy contained the control and video antennae that would transmit the signals from three tiny video cameras mounted in the nose cone. The vehicle was operated by a joystick, and video was viewed on a laptop computer. The electronics and control systems were beyond the scope of the mechanical engineering design project, and the students had assistance in selecting and assembling these components.

Figure 2. Remotely-operated vehicle.

The vehicle was tested successfully at Cuttyhunk Island, the last island in the Elizabethan Island chain that extends south of Cape Cod, MA. Video tape of local marine life proved the functionality of the system. This senior design project was a tremendous success, well beyond the expectations. The students worked incredibly hard, putting in many hours each week and throughout several weekends. In short, the Department Faculty were quite impressed by their efforts and the submersible they built.

This project was unique in that it was more system design and less of an analytical exercise. Students were required to do appropriate analysis to determine the specifications of certain parts, such as the pitch and yaw pumps, but the analysis was less structured than that of the tripod. However, any less rigorous task was more than compensated for by the difficult manufacturing and by the prototype testing that was performed. Students machined many of the complex parts such as the nose cone and tail section at a facility away from the campus that had more precise machining capability. One conclusion that can be drawn from this project is that systems engineering projects can be extremely successful, but it must be recognized that different aspects of the design process are emphasized compared to standard design projects.

The oceanographic tripod and remotely operated vehicle projects were completed when the senior design course was offered during one semester only. The projects below are the first for the new format of the senior design course and are works in progress at the time of this writing.

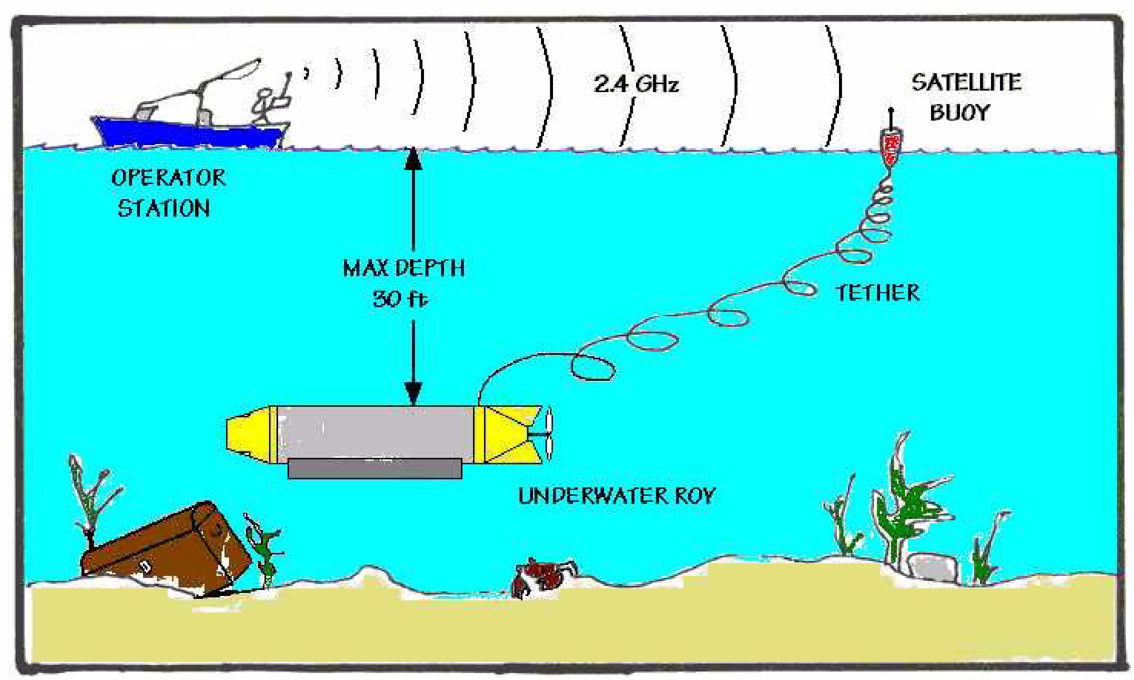

Figure 3. Schematic of ROV system.

Outboard Motor Mount

Outboard motors for small recreational boats are currently designed to have pitch control. This capability enables the user to adjust the propeller angle so that the maximum amount of thrust is gained from the motor. By adding a vertical adjustment to the control, drag can be reduced and further improve the efficiency and control of the boat. Two students are working on an outboard motor mount that would combine vertical and pitch control to optimize the motor thrust and fuel economy [3]. The optimal orientation of the motor is dependent on sea conditions, for example, in rough seas where there is the possibility of the propeller coming out of the water, the motor should be extended as far down as possible, whereas for calm seas, a motor that sits low in the water will have increased drag. The project is a work in progress, to be completed during spring 2003.

Expendable Ocean Profiler

Three students are working with researchers at the Center for Marine Science and Technology on the development of an expendable inexpensive ocean profiler that could take temperature data as a function of depth [4]. The device would cost less than $30, (not including the sensor) sink slowly to a depth of 50m, and return to the surface. One criterion that makes this instrument different from other autonomous ocean profilers is that this device will not employ a drop weight to resurface. It will instead have a pressure-triggered ballast system using a CO_2 cartridge for buoyancy control. The application of this device is to seed an area of the ocean with as many as a hundred or more of these instruments and take synoptic oceanographic data. The instrument should be easily located upon resurfacing and easily reset for another deployment. Lateral motion of the device due to local flow conditions during its mission is not of primary concern. The project is a work in progress, to be completed during spring 2003.

Acoustic Toy for Dolphins

The goal of this project is to design a small spherical toy that dolphin researchers would use to study dolphin behavior and response to acoustic signals [5]. The toy must be large enough so that a dolphin would not swallow it, yet light enough and strong enough to withstand both a dolphin bite and the potential impact of the toy being thrown from the pool and ultimately landing on a hard concrete surface. The toy must survive this harsh handling, maintain structural integrity to a depth of at least 20 ft, be rechargeable in a way that does not require it to be opened, have the ability to acoustically transmit a variety of signals, and be programmable using an infrared sensor. This project is a joint venture between the Mechanical Engineering Senior Design course and the Electrical and Computer Engineering Senior Design course. The mechanical engineers are focusing on the structural design and physical constraints, and the electrical and computer engineers are focusing on the internal system electronics and acoustic transmission and receipt. The project is a work in progress, to be completed during spring 2003.

Conclusion

Although these capstone design projects have been performed through the Mechanical Engineering Department, all are related to ocean and marine engineering. None of these projects was assigned to the students, and in two cases the topics were initiated by the students. This indicates a willingness of the students to participate in ocean-related projects. In fact, nearly one third of the senior design projects completed in the last 3 years have been ocean or marine-related. Further, four of the twelve faculty members of the Department have served as the technical advisors for these five projects. Only one of these has a degree in an ocean-related field. This indicates a willingness on the part of the faculty to be involved in ocean-related design projects. Many of these projects are interdisciplinary in nature, as oceanographic engineering is one of the most interdisciplinary engineering fields, and many of these projects have been supported by local industry or research facilities. In short, although ocean and marine engineering is one of the smaller engineering disciplines, there are many opportunities for the students to complete real-world projects.

References

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3. "Outboard Motor Mount", Greg Eitas and Clayton Moore, UMass Dartmouth Senior Design Project, 2002-2003.

4. "Oceanographic Profiler", Jeffrey Casale, Jon Merrill, and Rich Sullivan, UMass Dartmouth Senior Design Project, 2002-2003.

5. "Acoustic Dolphin Toy", Laura Furtado, Paul Liete, and Joe Silva, UMass Dartmouth Senior Design Project, 2002-2003.

Biography

Prof. Diane E. Di Massa holds four engineering degrees from MIT, including a Ph.D. through the MIT/WHOI Joint Program. Prof. Di Massa currently teaches senior and freshman mechanical engineering courses at UMass Dartmouth. Her research interests include robotics and autonomous vehicles, flow measurement instruments and flow-generated power devices, and electromechanical instrumentation.